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ABSTRACT

This report considers the underachievement and underparticipation of girls in mathematics. The facts are presented first, with illustrations from anecdotal evidence offered by teachers and others with an interest in mathematics education. Data from examinations at ages 16 and 18 in mathematics and in English are presented in graphs and discussed, followed by data from higher education courses, teachers, and professional mathematicians. In the next section, attitudinal evidence from both primary and secondary school levels is presented. Conclusions and recommendations for action at all levels are then described, with sections directed to classrooms, headteachers, mathematics advisors, teacher trainers, examination boards, educational publishers, parents, and industry and commerce. Theories and observations as to why girls underachieve in mathematics are included in an appendix, categorized by biological and genetic effects, general considerations, cultural and societal influences, and school influences. (MNS)

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Girls and Mathematics

The Royal Society and
The Institute of Mathematics and its Applications
1986

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A report by the joint

MATHEMATICAL EDUCATION COMMITTEE

of

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SUMMARY

Mathematics plays an important part in many aspects of our daily lives and a thorough grounding in mathematics is thus essential for all girls and boys during their education and training. Although mathematics is a compulsory subject to age 16, it does not follow that all pupils actively participate, or that their potentiality to succeed is necessarily equal. There is disturbing evidence, cited in the report, that girls, as a group, are seriously under-participating and underachieving in mathematics in comparison with their male counterparts, and increasingly so after age 11; many individuals, however, are very successful.

There are specific implications for the work of the following groups: classroom teachers, primary headteachers and mathematics coordinators, secondary school heads of mathematics departments, secondary head teachers, LEA advisers of mathematics, teacher trainers, examination boards, educational publishers, industry and commerce and parents.

The report outlines many and varied possible reasons for the under-representation of girls in mathematics. There is *no* convincing or conclusive evidence that it can be adequately accounted for by an innate or genetic disability at mathematics in girls. Consideration is given to various influences, in particular the image of mathematics in schools, girls' self-perception (their attitude to themselves and to mathematics), and their interactions with, and the expectations of, their teachers, parents and peers. Teaching styles, methods of classroom interaction, the examination syllabus and modes of assessment are also influential.

If all of the recommendations outlined in the report were implemented there would undoubtedly be an improvement in the way in which girls view mathematics; this would be to the advantage of us all. Indeed without a much increased output of mathematics graduates moving into a range of jobs, the UK faces considerable problems, not least in bringing forward the next generation of mathematicians. Nevertheless, in the world outside school there are strong pressures in many aspects of life to conform to sexual stereotypes. Despite equal opportunities legislation, the moves towards sexual equality in our society are slow. Traditional perceptions of mathematics as a 'male' subject persist and it is vital that they change. Improvement in girls' participation and achievements in mathematics will only happen when everyone shares this concern and works towards the same objectives. It is to be hoped that this report will assist in the process.

I. INTRODUCTION

1. Mathematics is generally acknowledged to be one of the most important subjects in the school curriculum. The subject is worthy of study for its own sake, capable of giving pleasure, interest and intellectual satisfaction. Mathematical skills are an essential grounding for science subjects in school, including biology, as well as for home economics, craft, design and technology (CDT) and geography. To be able to use mathematical language provides a means of communication and description that is increasingly used by economists, geographers and industrialists, as well as more traditionally in all aspects of science and engineering and their related career paths. As a tool, mathematics is useful in a variety of daily tasks and increases in importance as a person's studies in other areas deepen. Mathematical skills are increasingly important in a broadening spectrum and growing number of occupations, such as teaching at primary and secondary levels, nursing, social sciences, administration, physiotherapy, dietetics and clerical work.

2. Accordingly, mathematics is compulsory in the UK for virtually all pupils up to age 16 and it occupies a comparatively large share of their timetabled curriculum. Its relevance to school and post-school life is no less for girls than boys. Moreover, as we shall show, there is no evidence that the difference between the sexes in achievement in mathematics can be adequately accounted for by an inherent difference in ability. With good reason, therefore, educators and employers, in particular, have become increasingly concerned in recent years over the relative underachievement of girls in mathematics, notably from age 11, as compared with their male contemporaries. Furthermore, girls do not seem to recognize achievement in mathematics as being important to them. The disparity between the achievement of the sexes in mathematics is statistically significant, and the situation must be regarded as unsatisfactory and meriting continuing attention.

3. Against this background the Mathematical Education Joint Committee of the Royal Society and the Institute of Mathematics and its Applications set up a working party to study and report on the situation. The working party was chaired by Dr Christine M. Bondi, and comprised Dr Daphne Kerslake, Bristol Polytechnic; Mr David Lingard, Northcliffe Comprehensive School; Mr Peter Reynolds, Suffolk Local Education Authority; and Ms Ruth Townsend, Thames Polytechnic.

4. The working party's remit was to consider and report on the underachievement and underparticipation of girls in mathematics. In writing the report the working party has reflected the structure of the report *Girls and physics* (Royal Society–Institute of Physics, 1982) and aimed to update certain aspects of the Cockcroft Report (*Mathematics counts*, HMSO 1982). The working party has tried to present the facts (sections II and III) and illustrate them by anecdotal evidence offered by teachers and others with an interest in mathematics education. The report surveys the theories and observations as to why girls underachieve in mathematics (Appendix A) and recommends action at all levels (section IV).

In compiling this report the working party has been greatly helped by the anecdotal and statistical evidence submitted by teachers and others interested in the concerns of this report. The working party offers its grateful thanks to these individuals, listed in Appendix C.

II. STATISTICAL AND ANECDOTAL EVIDENCE

5. The most recent statistical information available, at the time of writing, on the participation and achievement of girls and boys in mathematics is for the year 1983. The sources of information publicly available, *Statistics of education—schools* (Department of Education & Science, HMSO), and the *University statistics: students and staff*, vol. 1 (University Grants Committee, Universities Statistical Record) are both published annually. Further specific information relevant to these purposes was supplied by the same offices. Extracts are provided in graphical form of examination entries and passes at CSE, O- and A-level, undergraduate and postgraduate courses at university and degrees awarded. The difference in performance in topic areas in mathematics was the subject of Assessment of Performance Unit surveys, and these are discussed in paragraph 34.

Examinations at 16 and 18

6. Figures 1*a–c* show the total numbers of girls and boys entering CSE, GCE O-level and A-level examinations in England and Wales in 1976, 1980 and 1984 (English and Welsh examination boards).

The numbers of entries of girls and of boys at CSE for mathematics and English are roughly even. However, slightly more boys offer O-level mathematics than girls and the disparity is large at A-level. The reverse trend is evident for English. The overall numbers of pupils entering for mathematics O-level have dropped; again the reverse trend is evident for English. Harding (1979) raises the question that 'if mathematics is a core subject (one that is taught to all pupils in the same way as English), why is it that substantially fewer pupils offer it in public examination?'

7. The examination grades achieved by boys and girls at CSE, GCE O-level and A-level in summer 1984 are shown in figures 2*a–c* (English and Welsh examination boards).

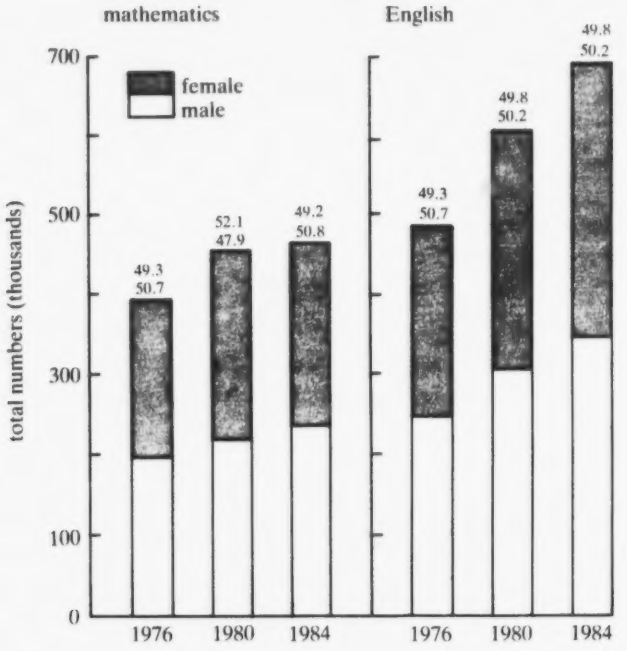


FIGURE 1*a*. Total numbers entering C.S.E. examinations (English and Welsh examination boards) in summer 1976, 1980 and 1984, by gender. The school population in England and Wales in 1985 at 15+ was boys 392 980, girls 377 539. The percentage of males and females entering examinations each year is marked on the bars. In all figures the top percentage figure applies to the top section of the bar, the lower percentage figure to the lower section of the bar.

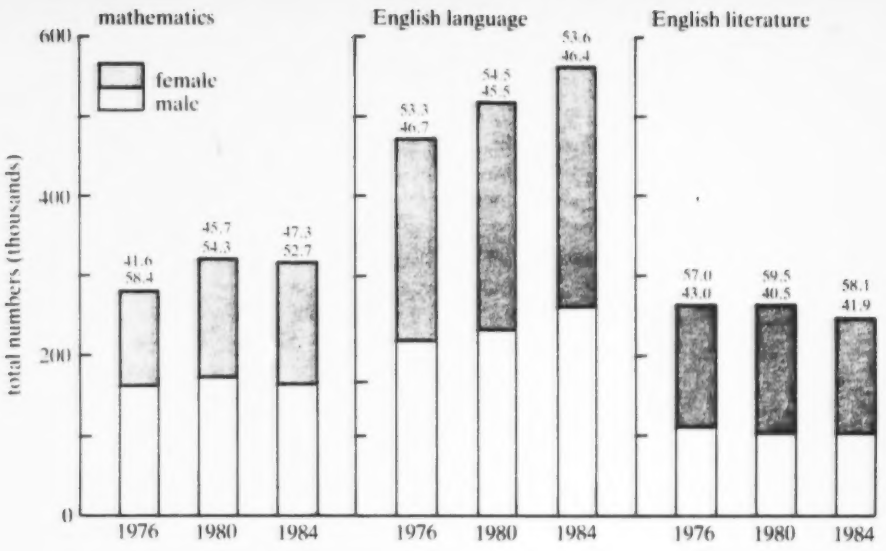


FIGURE 1*b*. Total numbers entering G.C.E. O-level examinations (English and Welsh examination boards) in summer 1976, 1980 and 1984, by gender. The school population in England and Wales in 1985 at 15+ was boys 392 980, girls 377 539. The percentage of males and females entering examinations each year is marked on the bars.

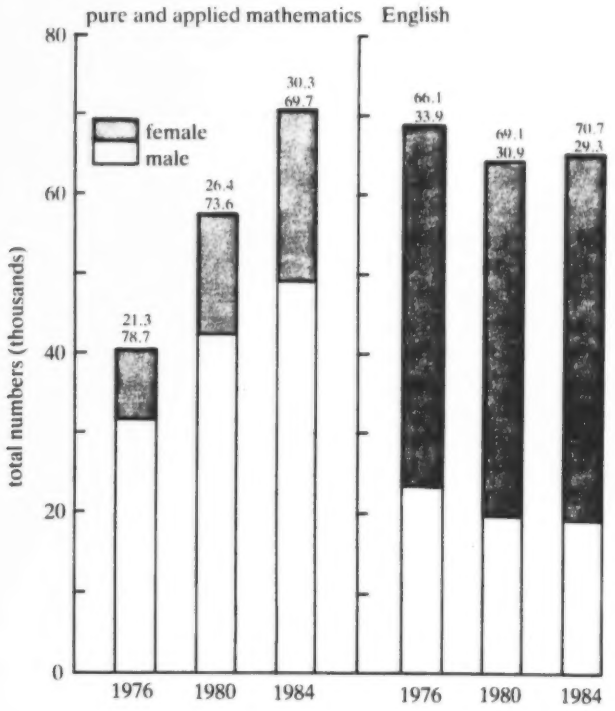


FIGURE 1*c*. Total numbers entering G.C.E. A-level examinations (English and Welsh examination boards) in summer 1976, 1980 and 1984, by gender. The school population in England and Wales in 1985 at 17+ was boys 79 476, girls 78 566. The percentage of males and females entering examinations each year is marked on the bars.

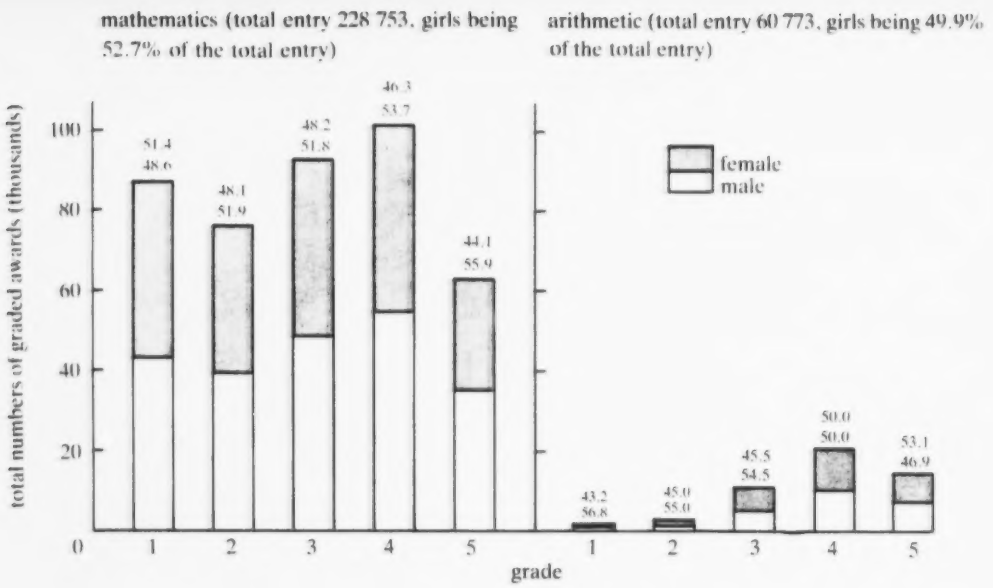

mathematics (total entry 228 753, girls being 52.7% of the total entry)
arithmetic (total entry 60 773, girls being 49.9% of the total entry)
total numbers of graded awards (thousands)
female
male
grade

FIGURE 2*a*. C.S.E. examinations achieved by grade and gender in summer 1984 (English and Welsh examination boards including Welsh common syllabus entries). The school population in England and Wales in 1985 at 15+ was boys 392 980, girls 377 539. The percentage of males and females awarded each grade is marked on the bars.

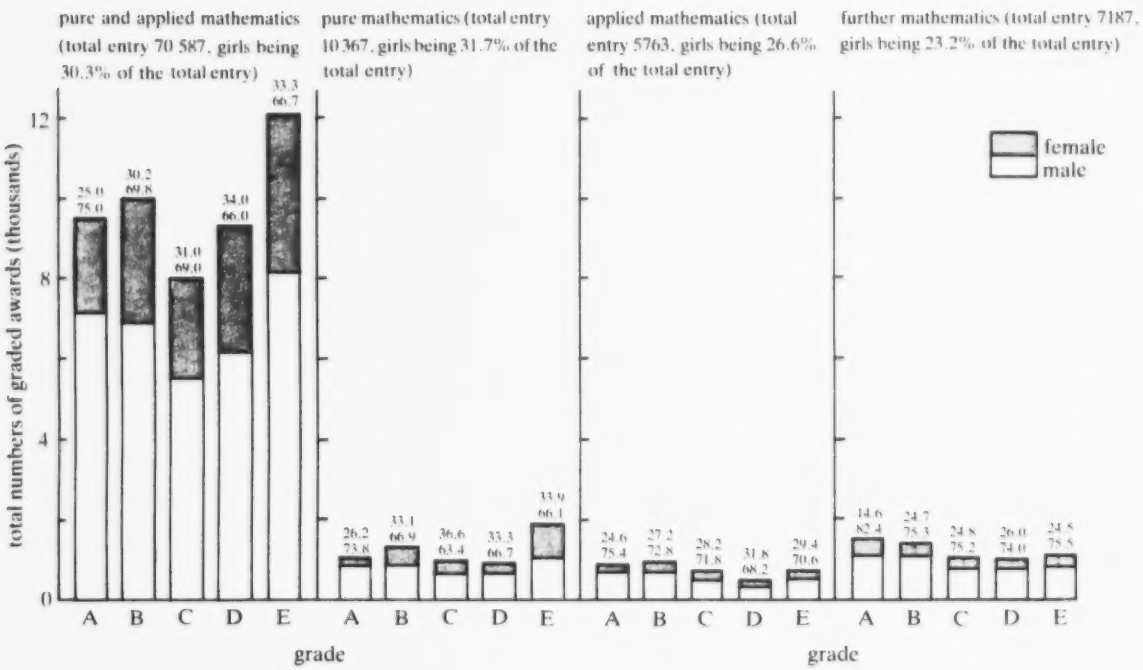

pure and applied mathematics (total entry 70 587, girls being 30.3% of the total entry)
pure mathematics (total entry 10 367, girls being 31.7% of the total entry)
applied mathematics (total entry 5763, girls being 26.6% of the total entry)
further mathematics (total entry 7187, girls being 23.2% of the total entry)
total numbers of graded awards (thousands)
female
male
grade

FIGURE 2*c*. G.C.E. A-level examinations achieved by grade and gender in summer 1984 (English and Welsh examination boards including Welsh common syllabus entries). The school population in England and Wales in 1985 at 17+ was boys 79 476, girls 78 566. The percentage of males and females awarded each grade is marked on the bars.

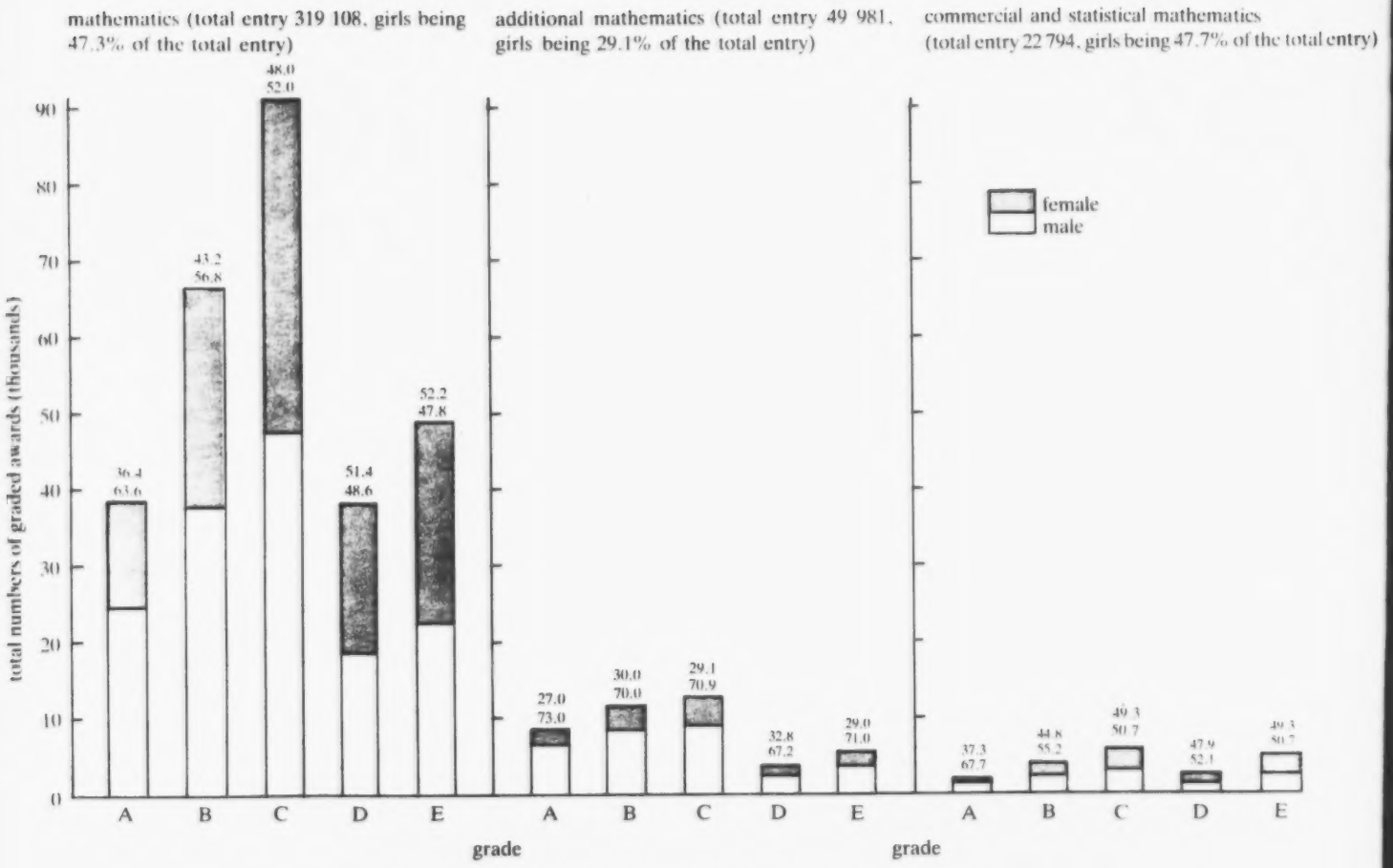
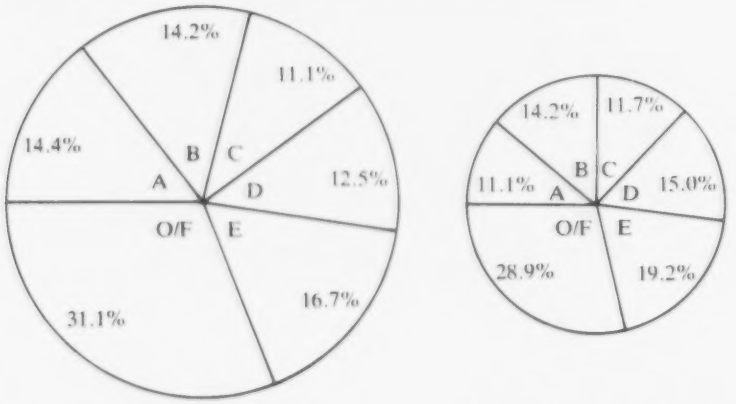


FIGURE 2*b*. G.C.E. O-level examinations achieved by grade and gender in summer 1984 (English and Welsh examination boards including Welsh common syllabus entries). The school population in England and Wales in 1985 at 15+ was boys 392 980, girls 377 539. The percentage of males and females awarded each grade is marked on the bars.

Examination results for boys and girls taking CSE mathematics and arithmetic differ little. At O-level, in mathematics, additional mathematics and commercial and statistical mathematics, a higher proportion of boys than girls achieve, in particular, grades A, B and C. A similar trend is more evident at A-level in pure and applied, pure, applied and further mathematics. Figure 3 shows two pie charts of the relative achievements of boys and girls by grade in pure and applied mathematics A-level, summer 1984.

Despite a large disparity in the numbers of female and male pupils that entered for the examination, the distribution of grades achieved is similar.



male (total entry 49 196) female (total entry 21 391)

FIGURE 3. Entry and achievement of males and females in A-level pure and applied mathematics in summer 1984 (English and Welsh boards including Welsh common syllabus entries), graded A–E and O/F (O-level/fail).

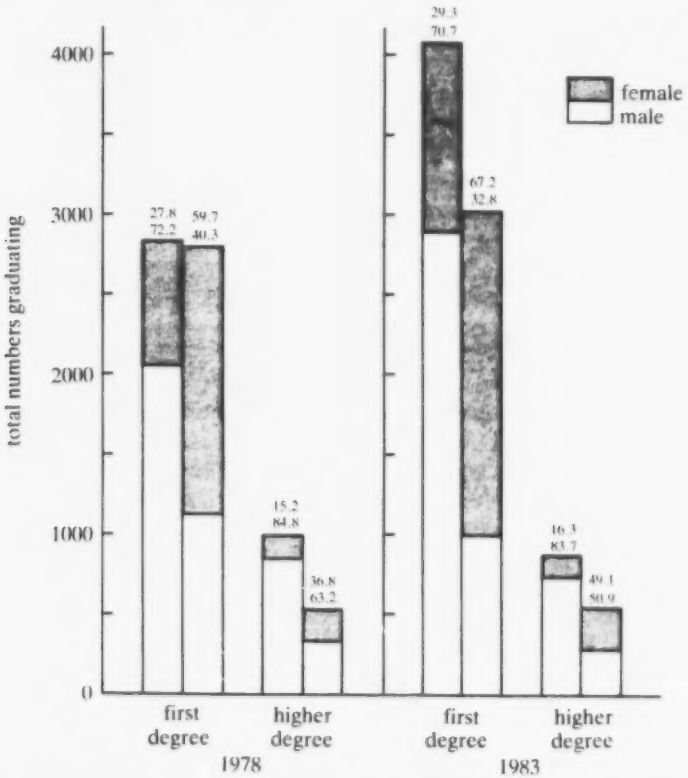


FIGURE 4. Total numbers of degrees obtained in Great Britain in 1978 and 1983. The percentage of males and females obtaining degrees is marked on bars. The figures for mathematics are on the left-hand bars, those for English on the right.

Higher education courses

8. Figure 4 shows the total numbers of first and higher degrees obtained in mathematics and English in 1978 and 1983. The increase in the total number of students achieving a first degree in mathematics is encouraging, but the ratio of females to males, although slightly better, remains unbalanced at both first and higher degree levels.

9. Figure 5 shows the class of first degree obtained by men and women in mathematics, English and for all subjects.

In each case, and to a greater extent in mathematics, a higher proportion of men attain a first class honours. In 1983 255 doctorates in mathematics were awarded to men and 25 to women, 87 doctorates in English were awarded to men and 47 to women.

Teachers

10. In 1983 there were 8065 graduate full-time teachers of mathematics in maintained nursery, primary and secondary schools; 5421 men, 2644 women. At 33% the proportion of women is lower than their representation among graduate teachers as a whole, 52%. This information can be further analysed: 77.2% of primary school teachers and 45.4% of secondary school teachers are women. A survey undertaken by this working

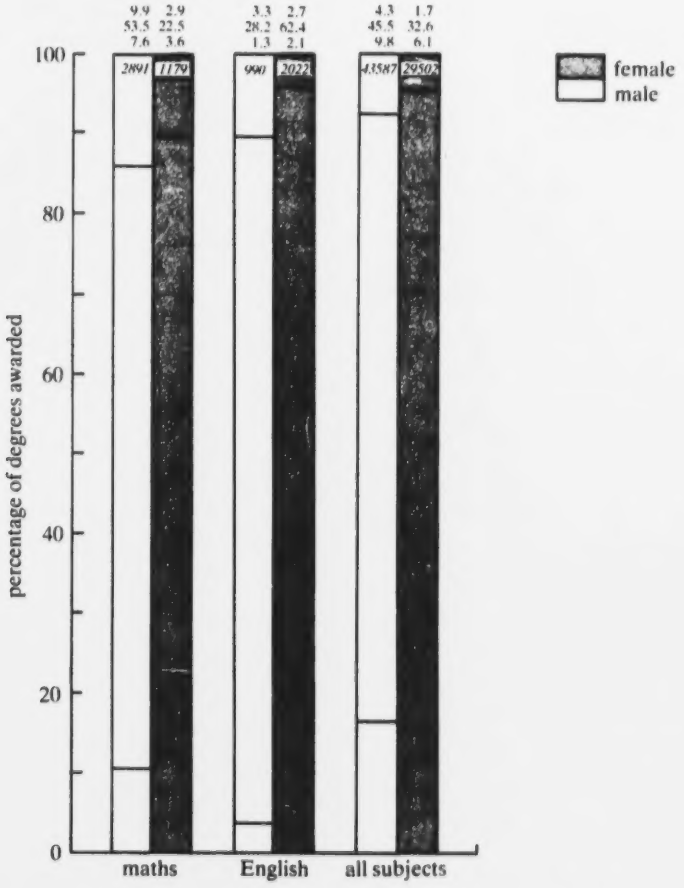


FIGURE 5. First degrees obtained in Great Britain in 1983 by gender. The percentage of males and females awarded each grade in each subject is marked on the bars. Each bar is divided into three sections. They are, top to bottom, first, other honours and pass degrees. Total numbers of males and females awarded a first degree in each subject are marked in italics in the top section of each bar.

group in 1985 of members of the National Association of Mathematics Advisers (NAMA), which includes members from most Local Education Authorities (LEAs), yielded information from 39 LEAs, and gave the results shown in table 1. These are shown against overall figures from *Statistics in education : teachers in service in England and Wales*, 1983 (DES).

TABLE 1. THE PROPORTION OF WOMEN PRIMARY SCHOOL HEADTEACHERS, SECONDARY SCHOOL HEADTEACHERS AND SECONDARY SCHOOL HEADS OF MATHEMATICS DEPARTMENTS IN ENGLAND AND WALES

	primary school headteachers	secondary school headteachers	secondary school heads of mathematics departments
1985 survey			
total numbers	7282	2062	2062
% women	42.7	15.7	14.7
1983 DES figures			
total numbers	22 323	4967	not available
% women	44.4	15.7	not available

The 1985 survey results closely parallel the situation in 1983. It is *possible* that overall figures for 1985 would be slightly lower than the survey figures; the mathematics advisers that responded to the survey are likely to be those sympathetic to the problem of the under-representation of women in teaching and, in particular, in mathematics.

Figure 6 shows that by comparison with male teachers a greater proportion of female teachers are concentrated in the lower grades of teaching. Heads of mathematics departments will generally be on scale 3 or 4. It should be noted, however, from anecdotal evidence that fewer women than men apply for senior posts.

Professional mathematicians

11. The numbers of men and women in the membership of the Institute of Mathematics and its Applications gives an indication of the proportions who are in professional employment as mathematicians in the UK. The most recent figures available are for 1985:

	male	female
Fellows	1199	33
Associate Fellows	2054	211

Similar information is available for the Royal Statistical Society:

	male	female
Fellows	3935	880

and for the Institute of Statisticians:

	male	female
Qualified Members	1116	184

12. For the 1985 British Mathematical Olympiad, 258 applications were received from 128 schools. Only 21 applications were from girls. The 1985 International Mathematical Olympiad, in Finland, was entered by 38 countries. There were 209 competitors of whom only 10 were female. However, one girl, from the Soviet Union, was one of the winners of a first prize. The other girl competitors came from Austria, Australia, Czechoslovakia, Cyprus, GDR, Italy, Hungary and Mongolia. The average score of the girls was 14.1; the overall average of all participants was 14.9. The British entrants to the IMO are not, however, a representative sample of the school population, coming largely from the independent, often academically selective, sector.

Since 1980 there has been an annual Devon Mathematical Olympiad. In 1984 537 mathematically able candidates entered from 45 schools in the county. The results were more encouraging than for the BMO and the IMO; 34% of the entry and 27% of the high scorers were girls.

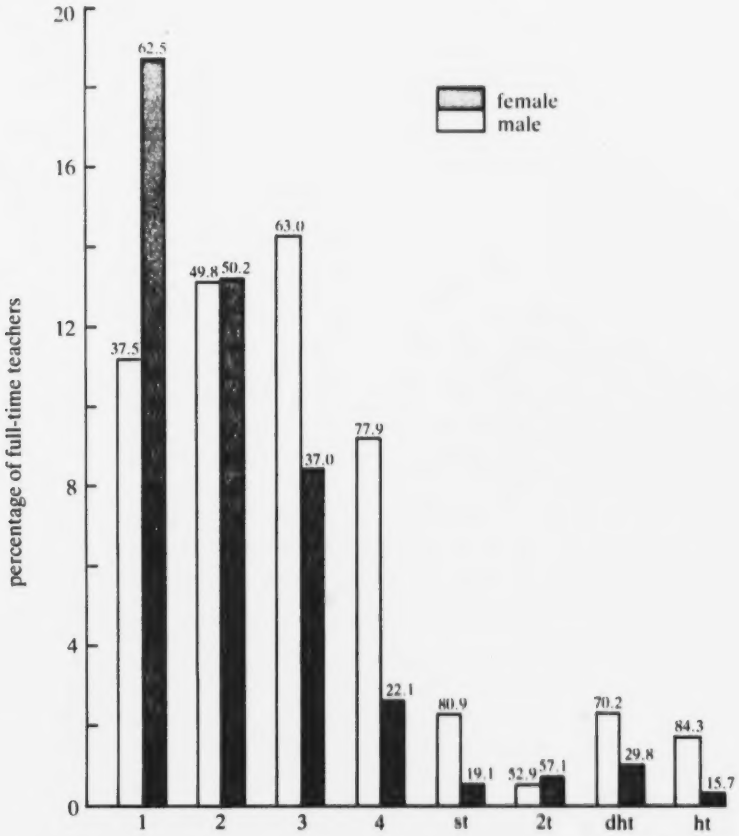


FIGURE 6. Proportion of male and female full-time teachers in secondary schools in England and Wales in 1983. The total numbers were male 132 606, female 110 308. The percentage of male and female teachers at each grade is marked on the bars. Grades are indicated thus: 1, scale 1; 2, scale 2; 3, scale 3; 4, scale 4; st, senior teachers; 2t, 2nd teachers; dht, deputy head teachers; ht, head teachers.

III. ATTITUDINAL EVIDENCE

13. In the following paragraphs we review the findings of the Assessment of Performance Unit (APU) surveys on mathematical development in primary and secondary schools, with particular attention to the differences in *attitudes* between girls and boys towards mathematics. The surveys undertaken by the APU at primary and secondary level have also shown that there are differences in the mathematical *performance* of boys and girls; three main features emerge. First, the differences lie mainly in the performance profiles of boys and girls across the various areas of mathematics. The best performance by boys, relative to girls, was in the applied and practical areas, of measures, rate and ratio. Girls did best in computation (whole numbers and decimals) and algebra, although by age 15 they were marginally behind the boys in these topics as well as in the others. Second, the top 30% of attainers accounted for most of the differences in performance between boys and girls at ages 11 and 15. In the 1978 secondary survey there were 61.5% of boys and 38.5% of girls in the top 10%. Similar results were obtained in the 1980 survey of 15-year-olds. Third, the main differences in performance were established by age 11. The profiles of attitudes to different mathematical topics parallel performance. To sum up, such differences as exist between the mathematics performance and attitudes of boys and girls have been established by age 11; the differences are mostly among top attainers. (Foxman 1985, draft review of APU findings 1978–82).

14. Three surveys were made in 1978, 1979 and 1980 at primary and secondary education level. The extent to which attitudes towards mathematics affect performance is unclear. One reason for assessing attitudes is that there are mutual influences between attitudes and performance. For example, it is generally conceded that attitudes affect the persistence of pupils when faced with an apparently difficult subject. They also affect the amount of mathematics that pupils will elect to study (Fennema 1979). Both persistence and mathematical experience have, in turn, been regarded as predictive of performance. Survey results in the USA that have indicated a relatively lower mathematical performance by girls, may be partly attributable to variations between the sexes in the number of mathematics courses taken (Fennema 1979).

15. **Primary survey.** Little difference was found in the level of girls' and boys' enjoyment of mathematics or in their perception of its usefulness, but there were significant differences in their opinions on how difficult they found mathematics. For example there were significant sex differences in responses in the following statements:

TABLE 2

		agree %	uncertain %	disagree %
I often get into difficulties with my maths	boys	46	26	28
	girls	54	27	19
I am surprised if I get a lot of maths right	boys	51	19	30
	girls	59	20	21
Maths often gets too complicated for me	boys	32	29	39
	girls	38	33	29
I don't think maths is difficult	boys	32	39	29
	girls	24	48	28

boys $n = 710$
girls $n = 690$

The third survey at primary level gave the pupils written tests in 11 subcategories. Boys' scores were higher than girls' in 9 of the subcategories with all but two of these differences being significant. Girls had higher scores in computation: whole numbers and decimals (to a significant degree) and in generalized arithmetic.

Boys expressed more confidence than did girls in their own ability in mathematics at 11 years old and had a greater expectation of success. They also expressed greater confidence in their ability to master specific mathematical topics and activities, in particular those involving measurement. Girls were less certain about the degree of difficulty presented by such activities. Hence, when children enter their secondary schools, a greater

proportion of boys than girls are likely to arrive expecting to be successful in mathematics; many girls arrive feeling that they are already failing at the subject.

16. **Secondary survey**. In each of the three surveys the notable discrepancy in attitudes between the sexes occurred in their perception of the difficulty of mathematics. Evidence from the 1979 report suggests that, in general, boys judged topics as easier than their success rate would indicate, while girls judged them as more difficult.

'I thought it would be very hard but now I find it quite easy'

(secondary school girl when faced with an unfamiliar task.)

Such differences in perception may also extend to parents' attitudes towards their offspring, witness the account we received from a mathematics teacher of a parent–teacher evening held for parents of fifth-form pupils expecting to stay on to sixth-form. The teacher spoke to two sets of parents of pupils of equal ability. The boy's parents were surprised when the teacher suggested that a double mathematics A-level option was over-ambitious; their son was so confident of his ability. The girl's parents were equally surprised at the suggestion that an A-level option in mathematics was realistic; their daughter had never felt that she was sufficiently able.

17. The survey did not explicitly study why girls lack self-confidence. The APU concludes from its findings that girls' attitudes are affected by a perception of mathematics as somehow 'masculine'. Although only a response to a single statement, a discrepancy was evident between the sexes in reacting to the statement 'When I do well in a maths test, I consider myself lucky' (a statement with which almost 20% more girls than boys agreed). The survey quotes research that suggests that men account for their success by ability and their failure by lack of effort, women account for their success by luck, and their failure by weak ability, and that both men and women are more likely to perceive mathematics as a masculine discipline. It is essential for girls and women to discount the luck theory, because if girls perceive their progress to be one of luck they are not likely to use it as a basis for future planning or subject choice.

'It's easy. I must be wrong' (girl doing sets and Venn diagrams).

The survey suggests that 'both attitudes in general and self-confidence in particular have been found to be more clearly related to the performance of girls than to that of boys. Furthermore, whereas high-achieving girls have been observed to have many of the same interests and attitudes towards mathematics as their male counterparts, sex differences tend to occur among those of middle and lower attainment. These girls have been found to be particularly vulnerable to lack of confidence.

'My maths does NOT deserve to be put in such a high class...I wish I could understand maths more clearly' (secondary school girl).

'I find maths quite difficult although I am a top stream candidate' (girl aged 15 who completed most of the written items in the questionnaire correctly).

18. In all three secondary surveys, the mean scores of boys were higher than those of girls in every category except for modern algebra in the 1979 survey. Boys' mean scores are highest relative to girls' in mensuration, rate and ratio, descriptive geometry and unit measures. Over the three surveys, the boys mean success rates in these areas were about 8% higher than girls. All these areas of mathematics are important in several secondary curriculum options such as the physical sciences, technical drawing and woodwork, which are all taken more by boys than girls. This higher attainment may result from differences in perception of usefulness of mathematics; boys perceive mathematics as useful for their subject options in school and their careers later on, girls do so much less.

'Boys may need more maths to do computer studies etc., these opportunities are not given to a girl' (girl age 15).

'The girls don't need maths as a housewife but men need them to support the house' (boy age 15).

In the USA Fennema (1979) has suggested that the 'single most important influence on studying mathematics is studying mathematics'. She added that where the amount studied was controlled, statistically significant differences between boys' and girls' achievement in mathematics tend to disappear. Although, as the Cockcroft Report notes, findings from the USA do not necessarily apply to the UK, the above data are compatible with the view that the difference in achievement is related in part to a difference in participation, which in turn is related to a difference in sex stereotypes.

19. Because of the age differences in the pupils, different attitude scales were used in the primary and secondary surveys; hence general comparisons cannot be made. However, in some cases the same opinion was expressed in both scales, although not in identical wording.

TABLE 3. RESPONSES TO SIMILAR STATEMENTS IN THE PRIMARY AND SECONDARY SURVEYS

			agree (%)	uncertain (%)	disagree (%)
Set 1					
primary	I find maths an easy subject	boys	22	42	34
		girls	20	46	34
secondary	Maths is easy for me	boys	25	17	56
		girls	10	14	75
Set 2					
primary	I think it is difficult to get on in life if you don't have much maths	boys	85	10	5
		girls	86	7	7
secondary	You won't be able to get on in life without a good knowledge of maths	boys	63	7	29
		girls	52	9	36
Set 3					
primary	I don't need maths much outside of school	boys	20	19	61
		girls	14	24	62
secondary	I don't find much use for maths outside of school	boys	23	7	69
		girls	28	4	65
Set 4					
primary	A lot of maths we do is a waste of time	boys	11	11	79
		girls	7	13	80
secondary	I don't see the value of most of the maths we do	boys	37	8	54
		girls	46	10	44

Six sets of statements were common to both surveys. The greatest shifts in attitude between primary and secondary levels occurred in the four, set out in table 3, that refer to the difficulty or usefulness of mathematics. Almost without exception, the shifts were negative (i.e. mathematics perceived as harder and less essential) and this was particularly obvious in the attitudes of girls. In terms of difficulty, girls' responses had become strongly negative from age 15, a move from a relatively neutral position at primary school age. Girls' attitudes to the value of school mathematics and its relevance to 'getting on in life' also changed substantially and to a significantly greater extent than boys.

IV. CONCLUSIONS AND RECOMMENDATIONS FOR ACTION

20. The mathematics education of girls in terms of their underachievement and underparticipation has been examined in the previous sections. A more detailed appraisal of the relevant theories and observations in recent educational research can be found in Appendix A. The findings are not clear cut, but the situation cannot be fully explained in terms of an innate difference of ability between boys and girls. There is no one answer to the conundrum. But what is clear is that at any one stage of a pupil's mathematical education many causative factors interact to influence relative mathematical achievement. However intricate the reasons, it is disturbing that girls are underparticipating and underachieving to a significant degree within an educational system with 'apparently' equal opportunities. We firmly believe that the situation can and must be changed, although we recognize that this will take a long time. Although we acknowledge that the situation has slowly improved, what is needed is an acceleration of that trend. To this end we have identified and recommended certain actions, some of which are applicable at different levels throughout the educational system and beyond, which we consider to be both important and practical.

21. HMI, in its report *Mathematics from 5–16* (Curriculum Matters 3, HMSO 1985), identifies 12 principles for classroom approach, one of which is 'encouragement to all pupils of both sexes and of different cultural backgrounds'. To quote from the report, '... specific efforts need to be made to ensure that mathematics is a less male-oriented subject than it is at present. To achieve this there must be higher expectations of what girls can do, with more encouragement given them to participate in all activities. Greater use needs to be made of a wide range of resources and activities which reflect the interests of all ...'. The report echoes paragraph 243 of the Cockcroft Report (*Mathematics counts*, HMSO 1982), which recommends that 'mathematics teaching at all levels should include opportunities for:

- exposition by the teacher;
- discussion by the teacher and pupils and between pupils themselves;
- appropriate practical work;
- consolidation and practice of fundamental skills and routines;
- problem solving, including the application of mathematics to everyday situations;
- investigational work'.

We consider that implementation of these recommendations in classroom practice should improve the participation and achievement of all pupils in mathematics, and in particular that of girls who appear to benefit from discussion in the classroom and solving 'real' problems (paragraph 60).

22. The Cockcroft Report identifies two strategies believed to be of particular importance in improving the mathematical performance of girls: 'the first is the need for appropriate careers guidance to be available to girls at an early stage so that their attention can be drawn to the fact that the lack of an appropriate mathematical qualification can exclude entry to many fields of employment. The second is the need for teachers to be aware of the differences in mathematical performance which at present exist between boys and girls.' In Appendix 2 of the Cockcroft Report, Hilary Shuard suggests that girls should be encouraged to realize that mathematics is as important for their daily lives, and in their future careers, as it is for boys. Girls now have the opportunity to enter all types of careers, many of which will make demands on their ability with mathematics. Boys as much as girls need to be aware of the importance of mathematics for girls and women so that boys do not unconsciously emphasize outdated stereotypes in their expectations of girls.

23. One of the last acts of the Advisory Committee on the Supply and Education of Teachers (ACSET) was to recommend to the DES ways to combat shortages of specialist teachers. In a report, *The recruitment of suitably qualified teachers in shortage subjects*, ACSET says, 'we support the arguments which have been advanced elsewhere in favour of encouraging many more girls to look towards mathematics, physical science and technology for a career'. The report calls for positive policies within and outside schools to eliminate sex stereotyping, and more publicity for careers in teaching and teacher training courses

designed to make clear that teaching mathematics is a worthwhile career option for girls. We obviously endorse this advice from ACSET and fully support the recommendations.

24. It is interesting to note that although a social stigma is attached to the inability to read or write, many people are apparently happy to admit that they have 'never been much good at maths'. This is particularly evident among many women primary school teachers who lack confidence in their mathematical skills. The introduction of O-level mathematics as a condition of training was intended to raise competence, but this does not necessarily remove the teachers' unease with mathematics. The same problem is reported among mothers who comfort their daughters by saying that they were never any good at mathematics either. It is most important that the public image of mathematics as not being 'the thing' for women is changed (paragraph 56).

The conclusions and recommendations in this section have been constructed to address directly the diverse groups that are influential in countering the problem. Each group has its own set of self-standing conclusions and recommendations, which look at the problem and the solutions, uniquely relevant to that group. It is, of course, to be hoped that the reader will also take the time to consider the full set of conclusions and recommendations in detail, and thus gain an overall appreciation of the scale of the problem at all levels and the most effective ways of countering it.

Classroom teachers

25. The evidence in section III indicates that girls and boys achieve the same overall performance in mathematics at primary level, although specific topics are differentiated by sex. Despite this, teachers and pupils regard mathematics as a subject at which boys are likely to achieve a higher overall performance than girls, and teaching styles and expectations are modified, often unconsciously, accordingly. Boys achieve significantly better in applying numbers and measures of length, area, volume and capacity, for example, whereas girls achieve significantly better than boys in only one area: computation of whole numbers and decimals, which figure decreasingly through the secondary years. The greater complexity of the mathematics that is introduced at secondary school requires a pupil to have gained confidence in both the conceptual and visuo-spatial aspects of mathematics in their primary school. By the end of primary school boys have developed more confidence than girls in these areas of mathematics. It is unfortunate for girls that as they reach puberty, when the social and peer group pressures are most likely to result in sex-stereotyped behaviour they are introduced to an approach to mathematics that requires the problem-solving, experimental approach, which boys have developed more than most girls of the same age. Nevertheless, we encourage this approach to teaching mathematics, and welcome its promotion in the new GCSE examination system. It is important that girls in particular develop these skills earlier; they should be encouraged to be more investigative, more curious and more adventurous in their mathematics and not to be allowed to set great store on being neat and tidy (paragraphs 14–18, 27(vii) and (viii), 58, 64).

Secondary school teachers of mathematics

26. The APU surveys suggest that by secondary school level girls are performing less well at mathematics than boys. The findings show that girls develop an increasingly negative attitude to mathematics at secondary school from a relatively neutral attitude at primary school. However, although girls lack confidence in their mathematical abilities and put their achievements down to 'luck', their lack of confidence is not related to their actual performance. The masculine image of mathematics perceived by girls is exacerbated at secondary level as the topics at which boys excel at primary school become increasingly useful and relevant. Girls react and begin to associate success in mathematics with an undermining of their femininity. The most influential factor in girls' attitudes to study is whether the subject is perceived as a 'male' or 'female' subject. This is much more significant, for example, than the like or dislike of a subject. Teachers can compound the problem at secondary school by only rewarding achievements that are appropriate to the pupil's sex (i.e. when girls achieve well at computational tasks and boys at solving problems). The evidence reports that some

teachers of mathematics in mixed secondary schools prefer to teach boys, presumably because by this stage they are either achieving better or participating more actively in class and are thus more rewarding to teach; many more teachers unconsciously project a prejudice against girls. This is disturbing as girls are more sensitive than boys to the teaching style and a teacher's behaviour. Girls and women are under-represented in mathematics textbooks aimed at all levels in schools, in particular at the secondary stage, which closely reflects the diminishing participation of girls in the subject (paragraphs 16–19,58–62,66–68).

Recommendations to classroom teachers

27.

(i) Be aware of possible hidden prejudices when considering the expectations of boys and girls with regard to their overall mathematical performance. Positive expectations of girls on the part of teachers should begin to foster positive attitudes to the subject from girls.

(ii) Be aware of having different expectations of mathematical performance for girls and boys. Expect girls as well as boys to be able to complete a mathematical problem that involves applied as well as arithmetical aspects, and praise them accordingly.

(iii) Encourage girls to use constructional toys, apparatus and equipment (e.g. Technical Lego and wheeled vehicles) that will develop visuo-spatial skills.

(iv) Be aware of sexism in mathematics textbooks and other teaching materials; if at all possible use mathematics textbooks in which girls as well as boys are shown actively using mathematics in pleasure and employment. Write to publishers when books show bad practice.

(v) Check your own performance against the guidelines given in teaching packs such as *Girls into mathematics*, recently developed by the OU and the ILEA.

(vi) Encourage all pupils in all aspects of mathematics; do not minimize the importance of those aspects at which girls tend to excel or, conversely, overstress the importance of aspects in which boys tend to excel. Modify course content and presentation where possible to utilize fully all aspects of mathematics and to allow all pupils to experience success rather than failure in the subject.

(vii) Introduce problem-solving skills to mathematics early, and avoid a right/wrong approach. Ensure that girls experiment with their approach to a problem.

(viii) Encourage all pupils to talk about mathematics and attempt to bring a 'social' (perceived as 'female') element to the teaching. Introduce group work and cooperative teaching styles; do not allow boys to dominate discussion in mixed groups or girls to defer to boys in discussion.

(ix) Avoid praising neatness and tidiness in girls' work for its own sake; do not confuse neatness with clarity of thought.

(x) Provide girls and boys with genuinely equal opportunities to be familiar with the use of microcomputers in their learning of mathematics, for example introduce 'girls only' as well as 'boys only' periods of access. Be aware that some software with creative opportunities, such as LOGO, is particularly successful in meeting the needs of girls.

(xi) Use parents' evenings to promote the value of mathematics for girls in many activities outside school, option choices within school and career opportunities.

(xii) Encourage girls as well as boys to take mathematics into higher education.

(xiii) Encourage women teachers to participate fully in in-service training opportunities and to take more responsibility for portraying themselves as confident and happy with mathematics.

Primary headteachers and primary mathematics coordinators

28. The evidence suggests that environmental pressures influence children in several ways. Environmental influences operate variously according to the organization of the school; this is the responsibility of the headteacher. In most primary schools the headteacher is in a position to implement changes in organizational policy. The research suggests that the attitudes of teachers towards boys and girls differ; boys are encouraged to be adventurous and investigative, girls are expected to adopt a more passive role. This is often reflected in teaching styles; girls respond best to group work. The pupils develop their attitudes to mathematics accordingly and boys begin to excel at topics in mathematics that require a more adventurous and open-ended approach even at primary school. The overall performance of girls and boys in mathematics is comparable at the end of the primary phase of education, but their attitudes to the subject are different. Even by age 11, girls are more likely than boys to attribute their success in mathematics to 'luck', often regardless of their known ability at the subject. The primary school has a responsibility to try to counteract the negative attitudes that develop in girls that will contribute to their underachievement in mathematics at secondary schools. The teaching materials traditionally used for mathematics in primary teaching tend to show boys actively achieving in mathematics, and girls adopting a more passive role (paragraphs 55–62,66).

Recommendations to primary headteachers and primary mathematics coordinators

29.

(i) Select teaching materials, wherever possible, that are not sexist.

(ii) Encourage teachers to enliven the classroom with displays of girls using and enjoying mathematics and of women mathematicians.

(iii) Bear in mind the value of an enthusiastic woman mathematics specialist in the primary school when recruiting staff.

(iv) Support and encourage 'girl friendly' teaching styles in the classroom (see also recommendations (vi), (vii) and (viii) above).

Secondary school heads of mathematics departments

30. Research indicates that environmental pressures combine to conspire against girls achieving and participating as successfully as boys at mathematics. A particularly influential aspect of a pupil's environment is the school, and the way in which he or she relates to each subject is influenced by the environment in which it is taught. It is clear that mathematical skills are important for pupils in school when making subject option choices and later on in their lives and careers. Many pupils, in particular girls, underestimate the importance and use of mathematics. Girls are discouraged by the lack of role models around them that involve mathematics. Most heads of mathematics departments and others with positions of responsibility in schools are male. Girls and women are often absent completely from secondary school textbooks and teaching materials (including microcomputer software), examination questions are often sexist and marking schemes (in particular multiple choice papers) may disadvantage girls. Girls will respond better to mathematics if they work together in groups, are taught to be adventurous and not to be over-concerned with presentation (the 'Tipp-Ex syndrome'). Many of these problems can be overcome only by a proper awareness on the part of teachers. However, this will only be possible within a department that enables girls to reach their full potential in mathematics to the same degree as boys (paragraphs 10,55,57–62).

Recommendations to secondary school heads of mathematics departments

31.

(i) Initiate, support and actively encourage equal opportunity policies in the mathematics department and ensure that the teachers collectively identify the problem of the underparticipation and underachievement of girls in mathematics.

(ii) As far as possible maintain a balance of men and women mathematics teachers. Girls taking A-levels in mathematics should be identified as role models to encourage girls lower down the school to continue with mathematics.

(iii) Participate fully in careers counselling so that all pupils appreciate the value and importance of mathematics.

(iv) Ensure that pupils appreciate the relevance of mathematics when making their option choices at age 13 or 14; liaise fully with other departments.

(v) Encourage group work, discussion and a more adventurous teaching style to allow girls to develop fully their problem-solving abilities.

(vi) Ensure that teaching materials, especially textbooks, do not perpetuate sexist stereotypes; encourage staff to organize lively displays in the department depicting girls' mathematical work or girls using and enjoying mathematics.

(vii) Where possible select non-sexist examination questions. Internal examinations should be balanced or neutral with respect to gender. Discourage multiple choice assessment.

(viii) Ensure that girls and boys have equal and separate access to microcomputers when they are used in the mathematics classroom.

(ix) As far as resources allow, ensure that the sixth-form timetable is able to accommodate an A-level mathematics option with a broad range of A-level subject options.

(x) Encourage women mathematics teachers to attend in-service training courses and to put themselves forward for promotion.

(xi) Where pupils are divided into sets for mathematics, it may be preferable for the upper sets to be taught by women teachers in the early years of secondary school.

Secondary school headteachers

32. The organization of a secondary school is largely the responsibility of the headteacher. The school organization dictates the environmental influences that the school will have on a pupil. Any changes of style in a school environment must be supported from the top. Children learn to perceive each subject as 'masculine' or 'feminine' at least partly from the school policy on timetabling, teacher allocation, classroom organization, groupings and segregations. Teaching style is also important, and the sex and attitudes of the teachers employed at the school will contribute to the whole school environment and that of each department. It has been shown that examination questions and certain styles of assessment can disadvantage girls. The new GCSE examination system must provide the opportunity to rectify these problems. The evidence shows that girls and boys develop different attitudes about mathematics that ultimately affect their participation and achievement in the subject and their eventual career expectations (paragraphs 17–19,57,58,64–68).

Recommendations to secondary school headteachers

33.

(i) Positive equal opportunity policies should be incorporated into every aspect of school organization.

(ii) Each department should be organized such that the subject is perceived as neutral and balanced; mathematics does not need to have a 'masculine' image.

(iii) As far as can be done within the present supply of mathematics teachers, bear in mind the benefits of a balance of men and women teachers in each department in making appointments .

(iv) Complain to examination boards when public examination questions show sex bias; discourage multiple choice papers. Insist that the new GCSE examination system is carefully monitored to identify sexism.

(v) Ensure that careers information for all pupils is not perpetuating sex-stereotyping and presents balanced opportunities for all pupils; girls as well as boys should realize that mathematics is important to them in many aspects of life outside and beyond school.

(vi) Encourage staff to attend in-service training courses on all aspects of their subject to keep them up to date with developments in teaching styles that are 'girl friendly'.

LEA advisers and advisory teachers of mathematics

34. For any lasting improvement to occur in schools the headteachers and departmental staff for mathematics will require positive support from the Local Education Authority and, in particular, mathematics advisers. The mathematics advisory team are in a unique position to spread a general awareness of the problems of underparticipation and underachievement of girls in mathematics to all the mathematics teachers in schools in their area. Special conferences, conventions and advice sessions all provide further opportunities to raise general awareness of the problem. Teachers require in-service training throughout their careers. The mathematics advisers have the opportunity to keep a theme, such as the disadvantages faced by girls in mathematics, running through all the aspects tackled by in-service courses. The evidence shows that individual teaching styles and the emphasis of specific topics in mathematics courses (course content) influence the achievement of pupils in mathematics, and girls are especially susceptible to these factors. Mathematics advisers are in a position to influence teaching styles by making firm efforts to follow up the recommendations in the Cockcroft Report, which are fully supported as likely to have more direct benefit to girls than boys. The poor, almost non-existent, representation of girls and women in mathematics textbooks after age 13 reinforces the impression among girls that mathematics is an unsuitable subject for them. With this attitude prevailing it is unfortunate that when girls look around them they usually encounter male-dominated teaching ratios, in particular in mixed schools, in the mathematics department and throughout the school (paragraphs 10,57–62).

Recommendations to LEA mathematics advisers and advisory teachers

35.

(i) Initiate and support LEA equal opportunity programmes.

(ii) Spread a general awareness of the problems of girls and mathematics to the primary and secondary teachers at all levels of reponsiblility in all schools in your area.

(iii) Feature problems of girls and mathematics as a subject or a background theme at meetings and courses (e.g. meetings for heads of departments), in particular with respect to careers.

(iv) In-service training courses for mathematics teachers should be designed with the same objectives in mind; this is a further opportunity to spread awareness to teachers who are unaware that they may hold hidden prejudices in their expectations of girls and mathematics.

(v) Positively initiate and support appropriate changes in teaching style (such as more group-work activities and more use of discussion material) and in the emphasis of course content by mathematics teachers to encourage girls in mathematics (as recommended in the preceding paragraphs); in particular persuade primary teachers to adopt a problem-solving approach with girls and boys before they move to their secondary schools.

(vi) Firmly discourage the attitude among teachers and pupils that mathematics is a 'male' subject.

(vii) Aim to achieve an equal balance of men and women mathematics teachers wherever possible within each school.

(viii) Advise schools to purchase mathematics textbooks that depict girls and women using and enjoying mathematics equally with boys and men. Write to publishers to draw attention to unsatisfactory material.

(ix) As far as is possible, encourage a balanced ratio of men and women on the advisory team.

(x) Consider holding or attending events such as the 'Be a sumbody' conferences, which aimed to change the perspective that girls have of mathematics and its relevance to their future, held at the Open University in 1982 and Thames Polytechnic in 1985.

Teacher trainers

36. Teacher trainers have a responsibility to influence wherever possible all the recommendations already outlined above. Teacher training courses aim to make students aware of different teaching styles with respect to the emphasis of course content in mathematics both in the education of new teachers and through in-service training of existing teachers of mathematics. Many entrants for teacher training courses will be women who already lack confidence in their ability at mathematics. More advanced courses held at teacher training colleges for prospective heads of departments and headteachers also provide the opportunity to demonstrate and reinforce the issue of girls' underachievement in mathematics. Teacher trainers are in a position to identify areas of sexist bias in examinations, textbooks and other teaching materials and to encourage mathematics teachers to consider the problem of sexism in mathematics and to work to counter it (paragraphs 18,19,57–63, 68).

Recommendations to teacher trainers

37.

(i) Promote a general awareness of sexism in mathematics; all student teachers should expect to have to consider the issue and appreciate the problems.

(ii) Promote the virtues of and positively encourage all of the practices suggested in the preceding part of this section when training new mathematics teachers. In particular encourage all student teachers to take a creative and expressive approach to their teaching and to introduce problem-solving aspects early.

(iii) Design in-service training courses similarly; existing mathematics teachers may hold hidden prejudices of which they are unaware.

(iv) Educate student teachers to monitor examination questions, assessment styles, textbooks and other teaching materials for all the features that discourage girls in mathematics.

(v) Those who monitor teacher training courses should ensure proper consideration of equal opportunities between the sexes in mathematics and, indeed, throughout the curriculum (in a similar way that the CNAA ensure proper multicultural education).

(vi) Promote mathematics as a subject that is equally acceptable and approachable by girls and boys.

Examination Boards

38. Many practising teachers are members of Examination Board subject committees and consequently have a responsibility to influence the activities of the Boards where possible. The evidence indicates that, given the current educational and other influences on girls, the traditional examination system for the assessment of mathematics includes various features that disadvantage them. It has been shown that girls react badly to failure. When girls have difficulties tackling a mathematical problem they are more likely than boys to abandon it than to continue through the question. Multiple choice assessment and negative marking schemes may disadvantage girls as they are less able, or willing, to take risks with their mathematics as a consequence of the environmental influences that have discouraged creative, expressive or risk-taking abilities in girls as they grow up. The competitive

nature and right/wrong approach of public examinations is a disincentive to girls. Continual assessment throughout the secondary years would encourage girls, as well as boys, to recognize their abilities in mathematics and to persevere with a problem.

Internal examinations can be monitored by headteachers and heads of mathematics departments. However, the choice available in public examinations is between which Examination Board is chosen and not between which mathematics question paper. This is of particular concern with respect to the arrangements for the new GCSE examination system. The University of London School Examinations Board has published a brief report (*Sexism, discrimination and gender biases in GCE examinations*, March 1985) acknowledging that a problem exists and recommending an anti-sexist policy. It is to be hoped that other Examination Boards are also aware of the problem and are willing to take positive steps to improve the situation (paragraphs 17,64–68).

Recommendations to examination boards

39.

(i) Design, encourage and approve assessment materials in mathematics that are neutral or balanced with respect to gender.

(ii) Where questions in mathematics are set within a social context take care to avoid stereotypes; consider the accessibility of the context to different groups of pupils.

(iii) Use continual assessment schemes as much as possible and, in general, offer modes of assessment that are less sensitive to mere attitudinal differences between the sexes. GCSE examination arrangements provide the opportunity for reform, and the consequent development of oral and practical assessment in mathematics is welcomed and should encourage girls without introducing any counteracting influence on boys.

(iv) The composition of mathematics subject committees within each Examination Board should be monitored for sex bias; the aim should be that the numbers of men and women be equal.

(v) Promote more 'girl-friendly' examination syllabuses; keep abreast of and support relevant curriculum development in schools.

Educational publishers

40. Much has already been discussed about mathematics textbooks and their possible influence on the underparticipation and underachievement of girls in mathematics. At secondary school level references to girls and women have in most cases largely disappeared in textbooks. The change coincides with the stage at which girls' problems become apparent and begin to increase—the time when their sense of femininity is highest and they are most sensitive to environmental 'messages' telling them what is or is not sex appropriate. Textbooks are providing no female role models to encourage girls at this age thus exacerbating the problem and doubtless in part causing it (paragraphs 17–19,61,62,68).

Recommendations to educational publishers

41.

(i) Illustrate mathematics textbooks wherever possible with girls and women using and enjoying mathematics. Show women achieving in all types of careers involving the use of mathematics.

(ii) Refer to females as often as males when posing questions. The activities described in the questions should be equally appropriate to both girls and boys.

(iii) Ensure that catalogues of educational apparatus and equipment depict girls and boys using and enjoying the products.

Parents

42. The evidence for substantial environmental influences on children both pre-school and within the education system is considerable. All children mimic adult behaviour, in particular that of the parent of their own sex. They frequently perceive their mothers as housewives with no other career aspirations regardless of their mother's qualifications, thus girls adjust their expectations accordingly and conform to an outdated sex stereotype. Toys are often marketed with a severe sex bias that reinforces sex-stereotyped behaviour and role-playing from children. The influence is so strong that even when given a free choice children select toys appropriate to their gender. These influences are compounded by parents who have expectations for their child based on its sex. Boys are allowed to be boisterous and scruffy, girls are expected to be passive and tidy. Once children begin school and are introduced to mathematics they are already behaving in a way that will influence their performance in a subject that has a masculine image. Parents tend to encourage and support boys to achieve at mathematics but merely console girls who find it difficult. Few parents would accept their daughter's illiteracy as casually as her innumeracy (paragraphs 17–19,53–57,68).

Recommendations to parents

43.

(i) Do not expect differences in mathematical participation and achievement in sons and daughters.

(ii) Encourage children to appreciate and mimic the behaviour of both parents. Girls and boys need the opportunity to share activities with both parents.

(iii) Draw attention to women with satisfying careers whom the children encounter around them and in books.

(iv) Children of both sexes should have access to both 'girls' toys' and 'boys' toys'; wherever possible persuade daughters to use toys that develop spatial, mechanical and problem-solving skills.

(v) Encourage daughters to be active, adventurous and energetic so that they develop similarly to boys with respect to the tasks in mathematics at which they excel.

(vi) Promote the vital importance of mathematics to *all* your children and draw attention to the mathematics used in tasks around the home.

Industry and commerce

44. One mathematics teacher wrote to us about a third-year class of high ability pupils (approximately two fifths of which were girls) visiting local industry and talking to female engineering apprentices. Many of the female pupils subsequently opted for 'male' subjects at age 14 and have maintained a keen interest in mathematics. The teacher reports, 'this may not be totally related to mathematics, but I feel that it is very important that the subject is not taught in isolation and that it is seen to be a useful tool to a successful career'. We welcome this approach and strongly recommend such liaison with local industry and commerce wherever possible. We suggest that it is the responsibility of the school to make the first approach.

General issues

45. If all the recommendations outlined above were implemented there would undoubtedly be an improvement in the way in which girls view mathematics. Nevertheless, in the world outside school there are strong pressures in many aspects of life to conform to sexual stereotypes. Despite equal opportunities legislation, the moves towards sexual equality in our society are slow. Traditional perceptions of mathematics as a 'male' subject persist and it is vital that they change. Improvements in girls' participation and achievements in mathematics will only happen when everyone perceives the problem and works towards the same objectives. It is to be hoped that this report will assist in the process.

APPENDIX A

Theories and observations

Introduction

46. The evidence (sections II and III) strongly indicates that girls and women underachieve and are under-represented in all aspects of mathematics and its uses. Many theories have been put forward to explain this, and they are based broadly either on the idea that such differences are innate, or that they are socially and culturally learnt. Whether the differences are innate or learnt or the result of a combination of factors remains in dispute. In the following paragraphs we outline briefly some of the major findings. It is acknowledged that in some of the research quoted the sample sizes studied were small.

Biological and genetic effects

47. That girls and boys differ physiologically cannot be denied. Research suggests that there are also small differences in the mean values of particular aspects of IQ tests: girls have superior verbal ability to boys whereas boys have superior visuo-spatial skills (Yen 1975; Kail *et al.* 1979; Carter *et al.* 1983; Samuel 1983). Walden & Walkerdine (1983) have defined spatial skills as the ability to perceive relations in space and to visualize objects in three dimensions. The three most common biological explanations of sex differences in spatial ability are:

(i) a recessive gene on the X-chromosome that increases spatial ability in half of the male and a quarter of the female population;
(ii) a hormonal difference;
(iii) different brain lateralization in males and females (see e.g. Wittag & Petersen 1979, McGee 1979, Burton 1978).

The fact that the sex difference in mathematical achievement is small at the primary level, and becomes important only during secondary schooling, renders slightly less likely the view that it can be ascribed to an innate difference, though the possibility remains that an innate difference could operate through, for example, hormonal changes at puberty.

48. Any innate differences in ability are unlikely to account for more than a small proportion of the differences in achievement. They involve only small (but sometimes significant) differences in the means of the two sexes and there is extensive and almost complete overlap in the distributions. Burton (1978) comments that they could not account for more than a small proportion of the differences observed in achievement. In addition, significant differences in spatial skills are evident only at the lowest level of mathematical participation (Armstrong 1981) and can usually be compensated for by verbal skills (Burton 1978). In a Further Education Unit (FEU) Report, *Balancing the equation*, Jacklin (1979) concluded that visuo-spatial ability is in part a by-product of mathematics learning, particularly of 'higher' mathematics classes where spatial concepts are taught. If women have the opportunity to study sufficient mathematics any deficiency exhibited in this skill will tend to disappear.

49. The evidence for differences in achievement is clear. For example, in the *International study of achievement in mathematics* (Husen 1967), boys scored better than girls in most of the twelve countries studied. Similarly, Benbow & Stanley (1980) in the USA reported that 'a substantial sex difference in mathematical reasoning ability ... in favour of boys was found in a study of 9927 intellectually gifted junior high school students'. The data were collected from the results of the Scholastic Aptitude Test in Mathematics (SAT-M), the USA college entrance examination that tests mathematical reasoning ability in 17-year-olds.

50. Differences in achievement do not necessarily imply comparable differences in aptitude. For instance, in the Husen (1967) study, differences between the sexes were reported in the mathematical participation of boys and girls (i.e. how much mathematics they had studied) in the countries considered, and these could have accounted for the differences in mathematical achievement (Fenemma 1977). The Benbow & Stanley finding

has been attacked on two main fronts. First the SAT-M is an entirely multiple choice examination; in some instances multiple choice assessment has been shown to favour boys (Harding 1979). Secondly, it has been suggested that the researchers have made faulty assumptions in their inferences of causation (Fenemma 1981). In particular, Fenemma criticizes the adequacy of SAT-M as a measure of inherent ability (as does Harding), the generalizing of the results of such a highly selective sample of students, the belief that girls and boys receive the same mathematics education before age 17, and the ignoring and misquoting of a large body of relevant data. Benbow & Stanley have been widely criticized for dismissing social and environmental factors as having an 'unquantifiable effect'.

51. The field of research into psychological sex differences is also hampered by sensationalist reporting by the media. Fenemma describes how the public perceives 'genetic characteristics' as immutable and that the media coverage in the USA of Benbow & Stanley's findings caused a moderate statement to become absolute fact in the eyes of the public. She stresses that the findings must not be ignored but that to consider them outside their social context is irresponsible. Whereas Maccoby & Jacklin (1974) concluded that there was evidence for established cognitive differences in verbal and spatial skills, Fairweather (1976) discusses whether there are *any* firmly established cognitive sex differences in view of the many assumptions made over the years and the misleading report by the press. Weiner (1980) is also critical that Maccoby & Jacklin do not consider *why* they reached the results they report. Maccoby & Jacklin (1981), in updating their previous work, noted:

(i) comparisons of groups of males and females yield differences only in average performance; the overlap in performance is considerable;
(ii) most studies include only white, middle-class American children, and may not be generalizable across cultures;
(iii) journals, in publishing and indexing, favour studies that show sex differences rather than those that report no differences;
(iv) when a difference is found it is often *assumed* to be natural.

52. The results of a study by Dwyer (1974) imply that sex differences in both reading and arithmetic skills are related more to a pupil's perception of the appropriateness of the subject to his or her sex than to other factors such as the gender of the pupil, a preference for a masculine or feminine sex role, or a like or dislike of the subject.

53. There is thus no evidence to indicate that biological or genetic factors are adequate to account for the considerable differences between the sexes in achievement in mathematics, and much evidence to show an extensive overlap in innate ability. The issue becomes that of enabling both girls and boys to achieve their maximum potential.

General considerations affecting the mathematical achievement of girls

54. There are many non-biological factors or influences that may explain girls' underachievement in mathematics. These can be categorized under three broad headings. The expectations of women and girls by society at large determine the extent to which girls participate and achieve. School influences suggest that mathematics is taught in schools in a way that favours boys (it is not 'girl friendly'). Attitudinal influences suggest that girls' underachievement relates to their negative attitude to mathematics.

Cultural and societal influences

55. The cultural and societal environment in which children grow up has a significant effect on the expectations that they develop. As Burton (1978) puts it, the sex of a child determines the expectations of parents, teachers and peer group. From infancy children's ideas about appropriate roles and behaviour are influenced by the actions and attitudes of their parents and other adults in their environment. Many facets of experience outside school may combine to generate in children concepts of mothering, of fathering, of behaviour appropriate to their sex, of manliness or of womanliness (Weiner 1980). There are several possibly interrelated hypotheses to explain how children acquire sex roles.

Imitation is the most favoured explanation, i.e. that girls copy their mothers, boys their fathers. Fox (1981) suggests that mathematically able girls experience some anxiety that their 'unfeminine' mathematical ability is unacceptable to their peer group. Commercial advertising on television, and elsewhere, does little to allay this image. A recent advertisement for Kellogg's Rice Krispies features two small boys suggesting that a girl in their class who is good at mathematics looks like one of the funny looking 'Ricicles' people. The advertisement was defended by Kellogg's as accurately reflecting the conversation and attitudes of boys of that age and also that it was created and written by a woman (GAMMA Newsletter 1984). Sex stereotypes are frequently perpetuated in this way.

56. Masculine and feminine sex roles are strengthened by adults and their choice of toys that are appropriate for girls and boys. Elinor Kelly (1981) suggests that many adults are not aware of the bias they show, but she accuses sales staff and package designers of perpetuating traditional stereotypes in their display and design of toys. In a USA survey, toys such as Meccano, which taught engineering principles and spatial skills, were marketed exclusively for boys. Recent evidence suggests, however, that the sex bias in the packaging of toys in England has largely disappeared. Nevertheless, the traditionally masculine toys are varied, complex and expensive; the traditionally female toys are simpler and anticipate passive and solitary activity. Evidence on the differential access at home to microcomputers for girls and boys is considered later in this section (paragraph 63). Straker (1985) suggested that children who come to school having already played at home with wheeled vehicles, clockwork or battery-powered toys, a calculator or a computer, are more likely to enjoy and benefit from the technological, scientific and mathematical experiences they will have in school. Books and toys are only part of the socialization process. It seems that the roots of children's analytical development lie in early childhood, with the attitudes of the parents, particularly the mother. Maccoby (1963) reported that 'the mothers of girls who were best at mathematics and spatial tasks often left their daughters to solve problems by themselves, and those boys who were poorest at mathematics had been "overprotected".

We are aware of other cultural factors that may affect participation and achievement by girls in mathematics, but do not have sufficient information to assess their importance. Whether or not these differences in gender stereotypes reflect or arise from small differences between the sexes in innate ability is not important here; the overlap between the sexes is virtually complete, with many girls achieving more in mathematics than many boys. The stereotypes mitigate against achievement by the girls.

School influences

57. The impact of schooling on boys and girls is an important element in the analysis of mathematical achievement. Pupils generally meet mathematics for the first time at school where it is given high priority. There is evidence that mathematics is regarded by both primary and secondary pupils and teachers as a subject at which boys excel. However, Maccoby & Jacklin (1974) found few sex differences in mathematical performance between boys and girls before adolescence, which could be interpreted as due to differences in expectation of achievement in mathematics by pupils and teachers rather than in actual performance. Up to age 11, and almost exclusively up to age 7, women teachers predominate, although only about 42% of primary headteachers are likely to be female (section II, paragraph 10). Many women primary school teachers on in-service courses admit that mathematics is 'not my thing', or that they have a 'mental block' with the subject. Until recently O-level mathematics was not required for primary school teaching; primary school teachers are, however, required to be fully literate. Women predominate in teaching at primary levels, but they often lack confidence in their ability in mathematics and consider innumeracy to be less a concern than illiteracy. Among secondary school teachers the balance between the sexes is more equal. However, only about 16% of headteachers of secondary schools and 15% of heads of mathematics departments (usually scale 3 or 4) are female (section II, paragraph 10). The paucity of women role models in positions of responsibility in schools where the teaching force is probably evenly balanced between men and women, exacerbates girls' low expectations in mathematics. Janie Whyld (1983) reports

that, 'the gender appropriateness of subjects is determined by the relevance they are generally believed to have to work as currently performed by men and women'. Fox (1981) reported that girls become more anxious about their career interests than boys because they have the additional worry of how the role of wife/mother fits in when they have so few models of women in positions of responsibility around them. These factors may combine to 'affect girls and boys in terms of both what they feel able to tackle [with regard to mathematics] and also their future career expectations' (Weiner 1980).

'We do maths because [we will need it] if we grow up to become a shop assistant' (primary school girl).

'More bosses of shops, people working in banks are men' (girl aged 15).

However, it may well be that teaching styles and teachers' individual behaviour could have more influence in inspiring girls to enjoy mathematics and to participate in it fully.

58. Weiner (1980), reviewing research on pupil–teacher interaction, reported that in the USA, at pre-school and primary levels, teachers hold girls and boys 'in equal esteem', but consider pupils' typical behaviour as different according to sex. Similar studies in British primary schools support the hypothesis that teachers' perceptions of boys and girls differ. For example, in an exercise carried out by Celia Hoyles, shown on BBC TV, a single set of qualifications were presented to a group of teachers but ascribed, for one group, to a child named Dennis and to another group to a child called Denise. The outcome? Quite different expectations and characteristics were attributed to the two children (with the hopes and expectations for Dennis much higher than for Denise). Lobban (1975) has reported that some primary schools segregate by gender, for example in calling the register or in lining up the pupils. Boys receive more discipline and blame than girls from teachers in all subjects as well as praise (Fennema 1980); high-achieving boys receive significantly more attention from teachers than do high-achieving girls (Good, Sykes & Brophy 1973). Fennema (1980) reports that teachers reward children when they reinforce their recognized skills (in this case that girls are more able at computational skills than boys and that boys excel at problem-solving tasks), thus confirming the child's sex stereotype. There is also some evidence that teachers are unaware that their attitudes towards boys and girls differ (Maccoby & Jacklin 1974). Sharma & Meighan (1980) conclude that 'the dominant cause of sex differences in mathematics attainment may not be that of potential or capability, but that of sex-stereotyping'.

59. These observations are supported by an experiment where the performance of girls in an all-girls mathematics set was compared with that of both boys and girls in an equivalent mixed set, taught by the same teacher. By the middle of the second year the girls in the all-girls set were still scoring in tests nearly as highly as the boys, but the scores of the girls in the mixed set had dropped behind those of the boys by an average of more than 20%. In the mixed sets boys continually monopolized the teachers' time in many ways, and the girls received much more individual attention in the all-girls set (Samuel 1983). Although such studies can be criticized for the undue influence of the teachers on the results, they are supported by more anecdotal evidence that we have received. For example, a mathematics teacher in a mixed comprehensive wrote saying 'there is no doubt ... that girls are more likely to develop their mathematical potential in a single-sex school than in a mixed one ... [in which] ... girls achieve well enough in years one, two and three, but as year four progresses the girls become less confident, much less willing to volunteer suggestions, and the boys take over. It happens with every group ... it is not that the girls stop working ... the boys are just willing to have a go in front of their peers and the girls are not.' Whether or not girls in single-sex schools perform better in mathematics, there are signs that girls participate more beyond age 16 in these schools. Nevertheless, there are other convincing educational arguments that apply when considering the relative merits of single- and mixed-sex schooling.

'If some girls do not know something, they keep quiet about it' (boy aged 15).

60. Styles of teaching in which pupils are not directly in public competition are said to provide girls with a better environment for learning mathematics. But whatever the style, investigative and problem-solving activities in the teaching and learning of mathematics will

help negate its perception as dogma (Sharkey 1983). A close and cooperative relationship between teacher and pupil in the classroom, such as is possible in some small rural schools, redresses the common imbalance between achievements by girls and boys in mathematics.

One teacher providing evidence wrote, 'the conclusions that I have drawn ... are that girls are not happy with the chalk and talk, bookwork approach that is so evident in maths lessons. They appreciate a variety of approach and can use their imagination—even sometimes carrying them on to do extra work at home, a rare occurrence in maths. They seem to respond when given the opportunity to express ideas and plan out their own ideas which are often surprisingly imaginative...variety is certainly worth a try.' However, in certain circumstances such teaching styles are less successful. Some girls are less happy with teaching styles that emphasize practical and investigative work than are the boys.

61. In a survey of primary school mathematics textbooks designed for ages 3–13 published between 1970–78, boys and men featured predominantly (Northam 1982). Only in books for infants did the female characters predominate. Both women and girls were depicted in a domestic sphere with few female figures actively involved in paid employment, especially in the mathematical world. Boys were portrayed as calculating, building, mending, being soldiers, whereas girls were watching men work, being driven in cars or being rescued! Adult women and girls had disappeared in the books aimed at 13-year-olds, the only mathematicians referred to were male. The masculine sex bias observed in primary school textbooks increased in middle and secondary school books. The decreasing number of women and girls portrayed correlates with the reported decrease in girls' involvement and achievement in mathematics from primary stage to examination participation at 16 and at 18. These findings confirmed earlier studies on the influence of textbooks on sex roles in mathematics (Berrill & Wallis 1976). Reports from teachers confirm the sex bias and the almost total absence of girls actively using and enjoying the products in catalogues of educational apparatus and equipment.

62. The masculine image of mathematics is perpetuated (and no doubt in part caused) by the image portrayed in primary and secondary mathematics textbooks. In the recent *Peak Book 4* (D. Godber, A. Brighouse & P. Patilla, published by Nelson) there are plenty of pictures of girls and boys of many ethnic groups doing mathematics. However, the only adults depicted in paid employment are male. A brief examination of the *Oxford Comprehensive Mathematics Book 1* (OUP) reveals photographs of men on a building site, playing cards, using a computer, a male shopkeeper and a bank manager. The text refers to a gardener, farmer, painter and captain as 'he'. All of the active people in the illustrations in the book are male, except for one female who is sewing. The book is redeemed to some extent by the problem that begins, 'Mrs Green earns more than Mr Jones or Mr King'. Even in the recent book *Foundation mathematics* no. 1 by Robert Glen (Heinneman 1984), the text is illustrated with comic pictures of men throughout. A woman is only pictured once throughout and then as Miss World! The Integrated Mathematics Scheme (Bell & Hyman) describes a day in the life of 'Metric Mary'—she goes shopping and buys food, polish, washing-up liquid and some material to make a skirt. It is unlikely that individual instances of sex stereotyping are all that important, but they add up to an overall picture that tells pupils that mathematics is not 'girl friendly'. (These examples were chosen, as far as possible, at random; they were not selected to show the 'worst case'.) An attempt has been made to meet these criticisms, for instance in the SMP 11–16 textbooks and the Inner London Education Authority learning resources branch book, *Count me in*; their use and the production of similar material is to be welcomed and encouraged.

63. *Role of microcomputers*. Microcomputers can be very effectively used in the mathematics classroom and are increasingly being used. Many of the most exciting developments, such as LOGO, can be made available through the power of modern computers and their software. But microcomputers remain a relatively scarce resource in the classroom and it is important that both boys and girls get a fair share of their use. Unfortunately, even when equal opportunities are provided, there is a noticeable tendency for the girls to be 'elbowed out' by the boys. Although no difference is found in the programming ability of girls and boys, girls are less interested in microcomputers and 'their association with mathematics often tends to frighten girls' (Beyers 1983). Conversely, girls are restrained

from making greater use of microcomputers in mathematics by the male image of microcomputers, calculators and other electronic devices perpetuated by advertising and other marketing campaigns that aim more at men and boys than at women and girls. Girls are less likely to have access to a computer at home and they are put off by the violent, male imagery of the majority of computer games. To assess how much the Christmas boom of computer sales had affected the number of microcomputers that children have at home, the MEP Primary Project conducted a sample survey in England early in 1985. Twice as many boys as girls had access to a microcomputer at home; nearly twice as many boys as girls had a pocket calculator. Far more boys than girls have a digital watch, and the group of children least likely to have any of these are girls who are single children or only have sisters (Straker 1985). The male image of microcomputers is only heightened by recent advertising campaigns aimed quite blatantly at a male market, 'If I gave your *son* a BBC Micro for Christmas, was it the best present you've [father] ever had?'.

We have considered microcomputers in the teaching of mathematics, but it was decided not to consider the special, but possibly parallel, matter of girls and computers.

64. *Methods of assessment*. Low achievement is often assumed to indicate low ability. However, evidence suggests that levels of achievement may be related to the modes of assessment. *What* is assessed is important, but so is *how* it is assessed. Different modes of assessment, such as the use of multiple choice or essay-type questions, directly correlate with the differing results for the two sexes (Murphy 1980). Inclusion of multiple choice papers as a mode of assessment may unintentionally create further difficulties for girls (Harding 1979). Against that, however, examinations on English language often include a multiple choice comprehension test, yet girls participate more and and achieve better in that subject. Possibly a bias introduced by mode of assessment is counterbalanced where a subject is 'girl friendly'. Structured questions seem to create the least sex bias. Multiple choice-style papers involve risk-taking when the pupil is unsure of the correct answer; research shows boys to be more confident about their abilities and more adventurous in their approach to mathematics than girls. It is to be hoped that newer forms of assessment being introduced for the GCSE examination system—course-work and oral—may avoid sex bias.

65. The male and female figures reflected in examination questions reflect sterotyped images of their sex; girls and women are seldom depicted outside their traditional roles. Sex bias is of particular concern because mathematics teachers cannot select examination questions in the same way as they can select textbooks or examples in textbooks. Ms Sharkey gives some examples:

'Four boys in turn toss a coin. What is the probability that the fourth boy will toss heads?' 'In a group of 27 men, 18 smoke, 16 drink beer ...' (Paper 1, London O-level syllabus B, January 1981).

'Last year a man and his family had their holiday abroad ...' (Paper 2, London O-level syllabus B, January 1981).

'A man had to deliver 21 parcels to a firm ...' (Paper 2 , LREB, 740000/A2, June 1981).

'An applicant for a job in which a high level of colour sense was required was given 10 colour cards each of a slightly different shade of green. He was told ...' (Statistics, LREB, 924809, June 1981).

It would be most worrying if similar examples were to emerge in specimen papers of the new GCSE examination system.

66. *The image of mathematics*. Keys & Ormerod (1976) found that attainment correlates more strongly with a pupil's perception of a subject than with measures of verbal–numerical and diagrammatic intelligence. They also suggested that girls' preferences for different subjects were far more strongly influenced by their perception of its easiness than are the preferences of boys. They concluded that '... strategies aimed at developing a pupil's liking for a subject (which should include careful phasing of conceptually difficult material and adequate praise and encouragement) as opposed to mere content coverage, are well worth the trouble and effort involved.'

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67. Hilary Shuard, in a review of the APU findings, notes that as children progress through the school curriculum some mathematical topics become more and others less important. The relative importance of computational skills declines sharply as pupils get older. The increasing use of calculators and computers is partly the reason. As pupils grow older and tackle more advanced mathematics, problem solving and the understanding of mathematical concepts become more important and are absolutely central to progress. Somehow, by age 10, more boys than girls are able to cope with these aspects of mathematics. Mathematics is felt by many to be impersonal, totally rational and dogmatic; characteristics that combine to give a masculine image of the subject. Sarah Sharkey (1983) observes that girls are 'only good at computation or rule following'. She examines why the balance of the curriculum seems to be weighted against the aptitudes of girls. Skill at computation, for example, might be thought to be an aptitude that most employers would seek in their employees. It is an unhappy coincidence that the areas in which boys are traditionally thought to be proficient are regarded as being important, whereas the topics at which girls succeed (e.g. modern algebra, computation) are made to seem less useful. Harding (1979) questions the criteria that determine a suitable O-level package for mathematics, as this is what determines the number of pupils for which the examination is considered to be appropriate. This begs the question of whether mathematics should really be a more 'difficult' subject than English at this level (more children enter O-level English than O-level mathematics) because, as it is, it is an 'effective barrier to the continued study and use of mathematics'.

68. Research indicates that girls who currently succeed at the subject are more likely to have more of the interests and traits associated with males (Sharma & Meighan 1980), which, with present modes of assessment, are the traits required to succeed at mathematics. As so much that concerns mathematics builds up a masculine image—the school environment and organization, the topics that are perceived as desirable, the textbooks, examination questions—girls inevitably develop unfavourable attitudes to the subject. These are described in some detail earlier. It has been shown that girls develop a fear of success that is related to their own self-image. They fear that achievement in mathematics might in some way decrease their sense of femininity and thus, in turn, cause them to experience some degree of social rejection by both sexes (Leder 1982). Whatever the reasons for mathematics acquiring an overtly masculine image, it is generally agreed that the balance should be redressed. There are educational benefits to be derived in girls and boys learning a form of mathematics that is not biased towards the needs of one sex, or one that is well related to the needs of all pupils.

69. To summarize, it is not possible to select any one answer as to why girls underachieve in mathematics. There is no convincing evidence that girls have an innate or genetic disability at mathematics adequate to account for the observed differences in achievement. **Many girls do, however, have unfavourable attitudes towards mathematics. The reasons for this are many and varied—sociological, psychological and cognitive factors are all involved. The 'masculinity' of mathematics conflicts with girls' sense of their own femininity, which has been determined from birth by the attitudes and influences of the people and things around them. Teaching styles, methods of interaction, the examination syllabus and modes of assessment also combine subtly to disadvantage girls.** It is, of course, acknowledged that there are many individual exceptions where girls like and do well at mathematics. This very fact should encourage all concerned to follow the suggestions outlined in the conclusions and recommendations (section IV) for turning these exceptions into the general rule.

'Maths is a fun subject, there are all sorts of different things to do. I like the harder type because it is a good challenge to my brain' (primary school girl).

APPENDIX B

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APPENDIX C

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